Capture and Cooling Working Group
Summary and Progress

C. T. Rogers
ISIS
Rutherford Appleton Laboratory
Reminder – muon collider facility (proton-based)

- Protons on target in high-field solenoid → pions, muons et al.
- **Clean up beam impurities**
- **Capture muons longitudinally**
- **Transverse and longitudinal cooling**
- Acceleration
- Collider ring

Capture and cooling
Working group
Job List

- Get hold of lattices
  - Check they run and we can reproduce results
  - Establish where lattices are missing or incomplete
- Develop and maintain hardware requirements
  - Liaise with magnet and RF teams as required
- Work on improving performance and developing new concepts
  - Especially final cooling
- Identify technical issues/risks
- Work on mitigating risk
  - MICE Results
  - Demonstrator design work
- Cost optimisation
  - E.g. rings
- **Please let me know if you would like to help!**
This talk

- Update on final cooling simulations (Bernd, Elena)
- Update on demonstrator simulations
- Comment on MICE analyses
Challenge is to get very tight focussing to get low emittance

Go to higher fields and lower momenta
  - Causes more longitudinal emittance growth
  - Chromatic aberrations introduce challenges
    - Elaborate phase rotation required to keep energy spread small
    - Move to low RF frequency to manage time spread
Now attempting to recreate and extend H. Sayed’s lattice

- Transverse optics is quite fiddly – very low $\beta$
- Getting a handle on tracking through single cells...
Beam matching (E. Fol)

- Build a periodic solenoid lattice in ICOOL
- Uses “realistic” model for solenoids
  - Based on sum over infinitely thin cylindrical current sheets
  - Extensive fringe fields
  - Include adjacent cell to get periodic solenoid field
- Developed matching algorithm
  - Produces okay results
  - Still some mismatch at the beginning (z=0)
    - Maybe need more than one adjacent cell(!)
  - Some emittance growth
    - With initial $\varepsilon_L = 0$
Single absorber simulation to cross-check ICOOL (Fano)
  - ICOOL tends to under estimate scattering compared to PDG
  - This is consistent with e.g. Moliere and MICE measurements in LiH

Heating effect in windows assuming $\beta$ for 50 T
  - $\beta = 6$ mm for 10 MeV
  - $\beta = 4$ mm for 4 MeV
Transverse cooling (B. Stechauner)

- Emittance change looks promising
  - Need to extend to lower emittances
  - Add in longitudinal phase space...
Lattice cooling (E. Fol)

- Started looking at chaining cells
  - No RF
- Energy spread already looking interesting
  - More cells → worse
- Working through layout for demonstrator
- Basic lattice for the cooling section shown previously
- Would like to understand collimation system
  - What is the muon rate?
  - What target is required?
  - What diagnostics can be used?
  - Can the demonstrator be compatible with e.g. nuSTORM?
Collimation System

- **Concept**
  - Dipole to do a first momentum selection
    - Not simulated
  - Collimation and RF to do phase rotation
  - Second dipole to do a second momentum selection
Lattice

- 1 m cell length
  - 0.5 T solenoids, 50 mm radius pipe
  - 0.125 m, 650 MHz RF cavities
  - 4 cavities per cell (and 4 cells)
  - 15 MV/m peak gradient
  - Running in “bunching” mode

- 0.7 T dipole
  - 45 degree bend

- All apertures are perfect collimators
- No electrons
- No pions
Lattice

- 1 m cell length
- 0.5 T solenoids
- 4 times 0.125 m 650 MHz RF
- 15 MV/m peak gradient
- 0.7 T dipole
- 45 degree bend
- All apertures are perfect collimators
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Intermittent bug

Dipole field

Solenoid field
Beam distribution at start

- Beam is supposed to fill the aperture **except** in momentum
  - Assumes not much collimation before first dipole (TBC)
- Momentum spread 10 MeV/c RMS
- Time spread long compared to RF frequency
Beam distribution after RF
Beam distribution after dipole
Beam evolution

Initially: 100k events
Finally: 440 events

Finally: 0.7 mm
Require: 0.5-1 mm

Finally: 2.5 mm
Require: 2-4 mm
Comments

- Looks like the time selection is not too bad
- Relies on quite tight energy selection in first dipole – not simulated
  - Alternatively, need taller RF bucket (more voltage)
  - (More voltage might be preferred by RF system)
- Quadrupole focussing worth investigating
  - Generate asymmetric beams
- What about pions/beam impurities?
Comment on MICE Progress

- Latest round of MICE analyses in progress
  - Several new datasets have been analysed
    - Solenoid mode (Tom Lord)
    - New analysis of flip mode (Paul Jurj)
    - Wedge absorber (Craig Brown)
    - LH2 scattering data (Gavriil Chatzitheodoridis)
  - Focus is on understanding/reducing systematic uncertainty
  - Student theses are in progress
  - Hope to bring to publication as students graduate
Conclusions

- Final cooling simulations are further developed
  - Building decent understanding of transverse lattice behaviour
  - Seek to add in longitudinal/RF simulations

- Demonstrator simulation developed
  - Snowmass submission has been invited on nuSTORM by mid-January
  - Would like to understand to what extent demonstrator is compatible

- MICE analysis is in progress
  - Study of systematic uncertainty